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The forecasted future operating environment is a complex, adaptive system, significantly interconnected and interdependent, and population-centric; one where U.S. military advantages are challenged by myriad state and non-state actors. It will be an operating environment in which unmanned systems use and their growing autonomy is not only planned but mandated and funded in U.S. law. Together, these trends challenge our current theory of command and control—and ultimately our concept of warfare. We are faced with a dilemma: how do Marines lead machines teamed with humans to achieve mission success in the future operating environment? The approach explored in this paper—the collaborative team—posits the integration of humans and machines in a way compatible with Marine Corps mission command and control.

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FUTURE WAR PAPER

Collaborative Teammates or Autonomous Peers?

Command and Control in Human-Machine Teams

**SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF OPERATIONAL STUDIES**

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THE OPINIONS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE INDIVIDUAL STUDENT AUTHOR AND DO NOT NECESSARILY REPRESENT THE VIEWS OF EITHER THE SCHOOL OF ADVANCED WARFIGHTING OR ANY OTHER GOVERNMENTAL AGENCY. REFERENCES TO THIS STUDY SHOULD INCLUDE THE FOREGOING STATEMENT.

Introduction

Marine Corps doctrine states, "No single activity in war is more important than command and control," making command and control the principal warfighting function in our system of warfare.[1] Command and control is how leaders, at all levels, leverage human decision-making to solve complex problems and create military advantages to win in the competitive, time-constrained operating environment. However, significant change is coming. The forecasted future operating environment is a complex, adaptive system, significantly interconnected and interdependent, and population-centric; one where U.S. military advantages are challenged by myriad state and non-state actors. It will be an operating environment in which unmanned systems use and their growing autonomy is not only planned but mandated and funded in U.S. law. Together, these trends challenge our current theory of command and control—and ultimately our concept of warfare. We are faced with a dilemma: how do Marines lead machines teamed with humans to achieve mission success in the future operating environment? In short, the Marine Corps must evolve its command and control doctrine, integrating human and non-human decision-makers so that our future system of warfare continues "winning battles."

Our current command and control paradigm decentralizes decision-making authority to the lowest level, allowing subordinates closest to the point of decision the freedom of action to solve complex problems.[2] This paradigm is being challenged by using machines that physically separate human decision-makers from the point of decision in the operating environment. Further compounding the challenge, humans in the future will not only physically be removed from the point of decision, they will in all likelihood be removed from the decision process.

This future began in earnest in when 2001 the U.S. Congress mandated that one-third of operational deep strike force aircraft be unmanned by 2010 and that one-third of all operational

ground combat vehicles be unmanned by 2015.[3] With that in mind, the Unmanned Systems Integrated Roadmap for Fiscal Year (FY) 2011 noted that U.S. unmanned air systems recorded over one million combat hours by November 2010, and that unmanned ground systems in Iraq and Afghanistan conducted over 125,000 missions by September 2010.[4] We see the continuing impetus to replace humans in DoD's FY2013 Unmanned Systems Integrated Roadmap: "unmanned systems must continue to reduce personnel, the single greatest DoD cost, through capabilities like autonomy and teaming."[5] Finally, the 2014 "Third Offset Strategy" calls for leveraging U.S. "core competencies" in unmanned systems and automation to offset challenges to U.S. military competitive advantages in the future operating environment.[6]

The above in mind, this paper explores the U.S. strategy to leverage autonomous machines within the context of the future operating environment using current command and control theory as a framework, a framework that recognizes war as the clash of human wills where uniquely human talents make war an art, not a science.[7] First, the context is set by briefly examining the 2015 Marine Corps Security Environment Forecast. Second, the framework for analysis is established using Marine Corps Doctrinal Publication (MCDP) 6: *Command and Control*. Finally, this essay will examine how human-machine teaming in the future operating environment may affect our current theory of command and control as portrayed in MCDP 6.

Context

Our future approach to warfighting will undoubtedly include more machines that can observe, orient, decide, and act far faster than their human teammates. Some machines will make decisions on their own, individually and collectively as a multi-domain, networked unit. Humans will still make decisions, but more often in collaboration with autonomous systems that provide

"decision cues." It is therefore important at this point to be clear about certain terms before proceeding further.

Definitions

Machines. In this essay "machine" refers to all unmanned systems, including air, ground, maritime (surface and subsurface), space, and cyber systems. This includes loitering munitions. Machines may be armed or not, but at a minimum they participate at some level in the decision to apply lethal or non-lethal force against materiel or humans.

Autonomy. There are many definitions of autonomy used in academic, government, military, and civilian circles that are not in agreement. For the purposes of this essay, autonomy is defined simply as the degree of independence from human participation that a machine is afforded in performing a task. A semi-autonomous machine requires some level of human participation to successfully complete a task. An autonomous machine can perform a task without any human participation—no human decision is required.

Artificial intelligence. Artificial intelligence (AI) is a field rich in theories and predictions. For simplicity's sake, this paper proceeds on two practical assumptions regarding AI. First, the current level of AI focuses on specific tasks of relatively narrow scope.[8] Second, AI will remain rule-based, search-based, and domain specific until about 2035.[9]

The Debate

The chief debate regarding machine autonomy is their role in decisions to apply lethal force against humans within the context of international humanitarian law and the law of armed conflict. While in-depth consideration of this debate is beyond this paper's scope, a brief summary of the machine autonomy debate facilitates understanding the current DoD policy.

The key organizations debating machine autonomy include the United Nations (UN) through the UN Human Rights Council and the UN Convention on Certain Conventional Weapons, the International Committee of the Red Cross, and Human Rights Watch, in conjunction with the Harvard Law School's International Human Rights Clinic. The debate focuses first on protecting life under international human rights law and the claim that "robots" "should not have the power of life and death over human beings."[10] Second, the debate focuses on accountability, specifically that "neither criminal law nor civil law guarantees adequate accountability for individuals directly or indirectly involved in the use of fully autonomous weapons."[11] The counter is that machine autonomy is not inherently illegal or unethical but does merit special consideration within the law of armed conflict.[12]

DoD Directive 3000.09 (21 November 2012) addresses the debate by "establishing DoD policy and assigning responsibility for the use of autonomous and semi-autonomous functions in weapon systems" and "establishing guidelines to minimize failures in these weapon systems that could lead to unintended engagements."[13] Human Rights Watch reviewed this directive and expressed concern that it remains in effect for only 5-10 years, excludes the Central Intelligence Agency, and provides a high-level approval process capable of circumventing any or all of the directive's constraints and restraints.[14] Notwithstanding, DoD monitors these issues closely as the armed forces seek to realize the full advantages of human-machine teaming.

The Future Operating Environment

As an expeditionary force in partnership with the Navy, the Marine Corps provides the capability to bridge the difficult seam between operations on land and sea—an amphibious capability assuring littoral access critical to our nation's ability to project power worldwide.[15] The Marine Corps must accomplish this task in a complex, congested, cluttered, contested,

connected, constrained, and coastal future operating environment—one where it must command and control human-machine teams operating in and around large population centers under conditions of volatility, uncertainty, chaos, and ambiguity.[16] With that in mind, this essay examines three areas of particular interest: the urbanized littoral, the "hybrid warrior," and the growth of "big data."

The DoD defines the littoral as two segments of the operational environment: "1. Seaward: the area from the open ocean to the shore, which must be controlled to support operations ashore. 2. Landward: the area inland from the shore that can be supported and defended directly from the sea."[17] Looking seaward, the Marine Corps faces the challenge of gaining access to increasingly urbanized littorals that contain 60 percent of today's politically significant urban areas within 40 kilometers of a coastline, and 75 percent within 240 kilometers of a coastline.[18] This growing trend incentivizes our adversaries' pursuit of technologies to challenge U.S. military advantages across all domains, particularly with regard to anti-access and area-denial capabilities that allow them to block the Marine Corps' ability to bridge the seam between operations on land and sea.

Looking landward, the Marine Corps faces the population challenges of the "megacity." The 3.2 billion people currently living in urban areas will grow to nearly 5 billion by 2030 with 60 percent living in cities, which, as previously stated, are in the littorals.[19] There are currently 29 megacities—i.e., those cities with over 10 million inhabitants—and by 2030 the UN projects 41 megacities, with only five found in Europe and North America.[20]

Considering the littorals as a whole paints a stark picture of an increasingly human-infested operating environment. The implications of the urbanization of the littorals with populations concentrated in cities creates very real problems. Culturally and religiously diverse

people living in tight quarters increase the stress on infrastructure, exacerbate food/water/energy shortages, impose negative environmental impacts, give rise to non-state actors hiding/operating in population centers, and render coastal populations vulnerable to natural disaster. And yet the Marine Corps will be required to operate in these areas and respond to crises in the urbanized littorals.

So, what attributes do the Marines require to respond to future contingencies in the urbanized littorals? The Marine Corps Warfighting Laboratory categorizes these attributes into three domains: cognitive, physical, and moral. The so called "Blue Hybrid Warrior" (referring to Marines fighting and winning in future hybrid wars) calls for abilities ranging from the intangible (honor, empathy, compassion, and humor) to the tangible (speed, accuracy, endurance, and reaction time).[21] Identifying and enhancing these abilities is crucial, because while we appreciate the immutable nature of war, "its mental, moral, and physical characteristics and demands," we must also anticipate the character of future warfare so that we can continue to recruit morally, mentally, and physically qualified individuals.[22]

The character of future conflict will exist concomitant with a world of "big data," one that makes many aspects of the environment increasingly transparent for both the Marines and their adversaries. State and non-state actors alike will be able to harness information, technology, and social media to act upon and interact with target populations. [23] There will be no monopoly on offense, defense, and exploitation in cyberspace.

Thus, the future operating environment presents the Marine Corps with opportunities as well as challenges operating in the littorals. The increased urbanization of the littorals and concentration of population in cities—especially the Megacities—will limit the utility of force and drive the need for very precise weapon systems that limit collateral damage. The very real

"people problems" of the megacity will require Marines with the intangible attributes required for working with diverse populations and the tangible attributes of increased lethality and precision at a time when U.S. budgetary concerns seek to substitute technology for manpower and soft power for hard power.[24] The ready availability of "big data" to both the Marine Corps and its potential adversaries makes the speed of decision-making more critical than ever. All told, these factors foretell an extremely complex future operating environment where humans and machines operate together, and the entity that observes, orients, decides, and acts the fastest will generate the tempo necessary to win.

Command and Control Theory

Command and control is the key to how the Marine Corps fights and wins in complex environments. Decision-making is central to command and control—whoever can decide faster gains a tremendous advantage.[25] People, information, and the command and control support structure form the basis of the Marine Corps system of command and control enabling commanders to push decision-making to the lowest level, thereby encouraging the initiative and the speed required for tactical innovation and operational tempo.[26] But how do Marines lead human-machine teams to generate the operational tempo needed in the complex future operating environment when the doctrinal command and control system is designed exclusively for human decision-making?

To answer this question, we require a command and control concept that includes both humans and machines. At its very core, command and control is a feedback loop with command as initiating action and control providing feedback. The Marine Corps uses the late John Boyd's OODA "loop" (observe, orient, decide, act) as the basic conceptual model of command and control.[27] Decentralized command and control pushes OODA decision making down to the

lowest levels to support the Marine Corps philosophy of maneuver warfare. The basic OODA loop is described below to facilitate our continuing discussion of human-machine teaming:

- Observe: *Data*—the whole of the *operating environment*—continual *feedback* on *our action.*
- Orient: *Synthesis*—knowledge placed in the *correct context* for *understanding.*
- Decide: *Decision* regarding a course of action—and the *authority* and *accountability* inherent therein.
- Act: *Decisive* action—*faster than the enemy*—continuous OODA loop action to *inform* action.

With the above in mind, the command and control of human-machine teams is most often described in the relevant literature from the human point-of-view, asking "where is the human in the loop?" In *An Introduction to Autonomy in Weapon Systems,* Paul Scharre and Michael C. Horowitz provide a simple, clear definition summarized as:

- Human-in-the-loop (semiautonomous); machine dependent on human input to complete loop
- Human-on-the-loop (human-supervised autonomous); machine independent; human monitored
- Human out-of-the-loop (fully autonomous); machine independent

The above definitions provide a common point of reference for later discussion regarding the broad concepts for putting command and control of human-machine teams into practice.[28]

There are significant challenges to our current command and control system and human-machine teaming may compound them. Mission command and control acknowledges that precision and certainty are unattainable in war and sacrifices them for speed and agility through

low-level initiative, commander's intent, mutual trust, and implicit communications.[29] Low-level initiative, the ability to act without instructions, is crucial to mission command and control. This delegation of authority achieves tactical utility but does not absolve senior leaders from accountability for their subordinates' actions.[30] Commander's intent bridges the gap between the leader and led at all levels by clearly articulating the objective or task to be accomplished with a clear understanding of why and how it relates to the larger operational picture. Mutual trust recognizes that trust is earned and travels a two-way street both up and down the entire chain of command. Mission command and control demands mutual trust amongst the entire team because it is the cornerstone of cooperation with a positive effect on morale.[31] Implicit Understanding and Communication are intangible human abilities fostered through a common ethos and repeated practice and essential to maneuver warfare.[32] All four of these are inherent in leadership. Leaders foster the same through organizational culture, education, training, and example and not only influence but define decision-making within and across the borders of any organization.

Ultimately, our current human-centric system of mission command and control overcomes associated challenges through human solutions to generate speed and tempo. This creates a paradox within which human-machine teaming presents immense opportunities and yet at the same time challenges extant beliefs and doctrine regarding command and control as a warfighting requirement.

Command and Control Theory in a Future of Human-Machine Teaming

Perhaps ironically, the command and control of human-machine teams in the future operating environment will remain at its core a human endeavor. The critical factor will be the interaction between the humans and the machines. That said, the simple fact that machines are

teamed with humans will influence human decision-making. This will make machines an "ethical impact agent." The smartphone is an example. People talk, text, etc., while driving, despite the risk. The smart phone is simply performing as designed, but humans modify their behavior simply because they have the smartphone.[33] The exact impact of machine teammates on human behavior will reveal themselves over time, so vigilance is vital to recognizing them as soon as they occur.

Dynamic human-machine interaction will conflict with our military's current culture of command. Humans and machines will self-organize, creating new and modifying existing collaborative processes—distributed, network-enabled, agile command and control approaches—resulting in emergent behaviors in response to the operating environment and the tasks assigned.[34] As a result, where the human is "in-the-loop" will vary at any given time between the humans and the machines. A better, more fluid concept illustrating where the human is "in-the-loop" is the distinction between a coach and a quarterback.[35] Humans will *monitor* machines executing tasks (human-on-the-loop) to provide overall direction and make occasional adjustments, i.e., coaching. On the other hand, when humans *control* machines executing tasks (human-in-the-loop) to provide specific direction and make fine adjustments, they are quarterbacking. Humans will alternate between these roles and perhaps will perform both simultaneously for some tasks. This shifts human-machine interaction from a culture of command focused on controlling machines towards a culture of autonomy focused on teaming.[36]

In a future of urbanized littorals we can expect human-machine interaction to be very fluid. Moving seaward to landward, and then into the megacity, the complexity and human-centricity of the environment will increase. Human-machine teams will necessarily shift from coaching seaward to quarterbacking in the megacity. However, this is not absolute because both

coaching and quarterbacking will occur throughout the operating environment, influenced by many factors. Speed demands less human interaction with machines to maximize advantage. Conversely, a non-combat evacuation demands more interaction with machines to maximize advantage. Humans and machines will support and be supported by one another simultaneously across all domains depending on the context. Thinking of humans supporting machines may be uncomfortable; however, it is essential to a culture of autonomy to maximize the advantages of human-machine teaming.

Even with human-machine teams ascendant, our command and control system will continue to emphasize low-level initiative by pushing the authority to both decide and act to the lowest level, including to machine teammates. We must recognize that autonomy, whether human or machine, is the delegation of authority and responsibility but not necessarily accountability. This includes enough autonomy to allow the team to "fight hurt" in the event of adversary cyber or electronic warfare attack or human teammate casualties. Moreover, too much machine autonomy may cause human teammates to lose situational awareness, something the humans must retain in order to ensure the team's actions meet the commander's intent.[37]

Commander's intent will remain a human function. Machines will operate using method-task-purpose routines towards a desired end state defined in terms of enemy forces, friendly forces, and the terrain, which complements both current doctrine and forecasted AI capabilities. Machines will assist humans in monitoring their operations by collecting, sharing, and analyzing data and notifying human teammates of any changes to the team's mission. Humans and machines share a common OODA loop based on method-task-purpose and using common terms and definitions to form the framework of the interaction between the human and the

programming. This improves the human-machine team's ability to exercise initiative in the face of uncertainty.

Historically, uncertainty has been considered a fundamental aspect of war. The response has been either to pursue certainty for effective command and control or to accept uncertainty and learn to function despite it.[38] In current command and control doctrine commanders must make a fundamental choice to pursue certainty (detailed command and control) or to accept uncertainty (mission command and control). Human-machine teaming in the future operating environment provides an opportunity to shift from the strict dichotomy of current doctrine and render this historical choice into a false dilemma.

The Marine Corps has chosen to accept uncertainty as unavoidable and based its doctrine around mission command and control to achieve the tempo and the flexibility necessary for successfully exploiting opportunity. Mission command and control views war as probabilistic and unpredictable, based on chance and with no direct causal outcome (coin flip). This drives the Marine Corps emphasis on low-level initiative, commander's intent, mutual trust, and implicit understanding. In the future, human-machine teaming will allow for both mission and detailed command and control to be employed. The "four block war" concept is an excellent way to illustrate this point.

The "four block war" concept posits that Marine Corps units may find themselves conducting humanitarian, security, combat, and partner, advise, and train operations on any four blocks of the urbanized littoral.[39] In the megacity Marines will face the "four floor war." Within a single building they are on the roof aiding non-combatant evacuation, detaining adversaries on the twelfth floor, maneuvering offensively on the third and fourth floors, while monitoring the

adversary's subterranean movement.[40] This represents the complex, unpredictable, and uncertain environment where mission command and control has historically thrived.

Preparing for the "four block war" we provide plans and orders to Marine leaders that are as brief and as simple as possible in order to avoid overwhelming them with information as well as to encourage low-level initiative. In the future, their machine teammates will receive very detailed plans and orders and receive continually updated data on the whole of the operating environment. The Marines synthesize the plans and orders provided within the context of their mission and commander's intent to achieve understanding. The machines, using immense processing power and data access, continually synthesize their team's mission and those of other teams to develop and continually refine their own understanding. Marine leaders will intuitively decide on a workable course of action based on their understanding, experience, and the time available. The machines will leverage "big data" to arrive at an alternative solution, thereby giving the leader options.

The above example illustrates that human-machine teams of the future will possess the ability to use both mission and detailed command and control. Through collaboration they can develop more informed courses of action. The intuitive human is supported by an analytic machine. This allows the team to decide and act faster than the adversary, creating significant military advantage.

Conclusion

The real challenge to command and control theory and doctrine posed by human-machine teaming is not about machines and autonomy but rather about how humans and machines will interact. The approach explored in this paper—the collaborative team—posits the integration of humans and machines in a way compatible with Marine Corps mission command and control.

That said, mission command and control must evolve to reflect a culture of autonomy inclusive of machine teammates.

As noted before, command and control will remain a human enterprise, but one that can be made efficient and effective through collaboration with machine teammates. These teammates will allow us to simultaneously use aspects of mission and detailed command and control to observe, orient, decide, and act faster than our adversaries.

We are in a race against adversaries pursuing disruptive technologies and other ways to counter our traditional military advantages. We must therefore realize the full potential of human-machine teaming before our adversaries do. Human-machine teaming does more than offset the growing capabilities of our adversaries, it has the potential to change our future system of warfare in ways we do not expect and are only now beginning to seriously think about.

In the end, human-machine teaming is a rich topic for future research. Some recommended topics include a human-machine teaming concept of operations, organization of the human-machine force, preparing our military personnel for teaming with machines, human-machine communication, human augmentation, etc. The future is upon us and we must embrace human-machine teaming as the norm and no longer solely in the realm of science fiction.

Notes

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[19]*Marine Corps Security Environment Forecast: Futures 2030-2045,* 54.

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